contemplate ; and now that the science has taken its proper rank, I do not think many would wish to see it separated from its old companions, the tables.

Cambridge, Dec. 12, 1872.

Postscript.—In my paper, in the May number of the *Notices*, I expressed an opinion that certain facts "seemed to imply that Vlacq meditated a Dutch translation of his work [the *Arithmetica* of 1628] but that the tables intended for the purpose were bought and published by George Miller." That a Dutch edition was not only proposed, but actually published, is, I think, proved by the following extract from a letter from Briggs to Pell dated October 25, 1628. Speaking of the filling in of the gap in the *Arithmetica* of 1624 he proceeds, "But I am eased of that charge and care by one Adrian Vlacque, an Hollander, who hathe done all the whole 100 chiliades, and printed them in Latin, Dutche, and Frenche, 1000 bookes in these three languages, and hath sould them almost all." The letter is in the Birch MSS., and is printed on p. 55 of the *Letters on Scientific Subjects*, published by the Historical Society of Science, under the editorship of Mr. Halliwell. I intend to quote the whole passage in which the above sentence occurs, in a paper I hope shortly to communicate to the *Philosophical Magazine*, on the subject of Vlacq's and Decker's tables. In all probability, the Dutch copies did not sell, so that they were bought by Miller, and published with the English, in place of the Dutch introduction.

March 14, 1873.

On the Apparent Projection of Stars upon the Moon's Disk in Occultations. By John J. Plummer, Esq.

(*Communicated by Prof. A. S. Farrer, D.D.*)

Few phenomena have more constantly resisted a satisfactory scientific explanation than the well-authenticated though anomalous projection of the images of stars upon the lunar disk previous to occultation. In the *Memoirs of the Royal Astronomical Society*, vol. iii. the whole subject has been thoroughly investigated by Sir James South, and in a later volume (xxviii.) the Astronomer Royal has also given the question careful consideration. The former astronomer, after examining five several hypotheses in order to explain the origin of the phenomenon, is obliged to reject all of them, without assigning any other ; and the Astronomer Royal, though more happy, does not appear to consider his solution entirely satisfactory. Indeed, it fails principally in those cases where the phenomenon has been seen at the dark limb, or where a

considerable interval of time, as from 4^s to 9^s, has been observed to elapse before the anomalous appearances have been terminated by the instantaneous disappearance of the star. Yet there can be no doubt, that very many instances of " hanging upon the limb," &c., can be satisfactorily explained by the hypothesis suggested ; and we are thus led to the conclusion, that *more than one* explanation must be given to account for all the recorded instances, and further that more than one cause may be in operation at the same time.

If, then, the true explanation of the phenomenon be complicated in this manner, it will be necessary to weed out all the doubtful and fairly explained cases, before we attempt to find another theory to satisfy those instances for which we have no plausible solution ; and this is the more necessary, when it is remembered, that the motion of the Moon's limb with reference to the star is never much more rapid than that of the star *Polaris* to the wire of a transit instrument, and may even be slower, should the occultation take place very obliquely to the limb, *i.e.* near the north or south points of the Moon's disk. Practical astronomers in localities where the atmosphere is not good, are only too well acquainted with the unsteadiness of approach of this star, and similar vagaries, if supposed to occur near the Moon's limb, would produce many of the appearances recorded as having been witnessed at occultations.

While engaged some months ago with the consideration of the Moon's libration, it appeared to me possible to frame a theory based on this phenomenon, which should serve as an explanation of the more marked cases of projection : and, as the matter was capable of exact calculation, I determined to submit it to examination at the earliest opportunity. The hypothesis as it presented itself to my mind was as follows. Assuming, as we have a right to do, from M. Hansen's investigations, that the moon's figure is not truly spherical, that the centre of gravity is not coincident with the centre of figure, it follows, that the lunar atmosphere (if any exist) must dispose itself equally on all sides of the point diametrically opposite to the centre of the lunar disk, as seen by us when the libration is at its mean state ; and further that the lunar atmosphere may be brought to the limb of the Moon whenever the libration is considerable.

The density of the outskirts of such lunar atmosphere, which is all we can have to do with in this inquiry, would of course be but slight; but should an occultation take place near the point of maximum libration, it may easily be conceived as sufficient to produce a refraction, capable of diverting the stellar ray to the extent which is witnessed. To test this theory all that was required to be done was to compute the amount of the libration effective at the point of the limb at which the occultation took place, for all those cases in which the projection has been noticed in its greatest extent. Unfortunately these cases are too few, especially during the last twenty years, to which period I have at present confined

my attention; but the result will show, that in no case I have ex-
amined has the phenomenon been witnessed when there was no
libration whatever at the point of occultation.

It is to be remarked that in tracing the origin of the phe-
nomenon to a lunar atmosphere, I am only resuscitating under
peculiar circumstances Sir James South's third hypothesis; but it
must be remembered that he has rejected it, nor could he have
imagined the important part which libration has to play in pro-
ducing it, the want of symmetry of the Moon's figure being un-
known and unsuspected till long after the date of his communi-
cation.

At the occultation of ζ *Tauri* on March 28th, 1868, I had the
good fortune to witness the phenomenon myself, and the event is
indelibly fixed in my memory by the surprising beauty of the
spectacle, as well as by the entirely unexpected nature of the
occurrence. The disappearance took place at the dark limb which
was distinctly visible, and the atmospheric circumstances were
eminently favourable. The star remained on the disk for at least
five seconds, and very possibly longer, and its distance from the
limb was considerable.* Calculating the libration for this obser-
vation, I find it amounted to 8° 16′, where it was at a maximum,
and 7° 14′ at the point of disappearance. Both these angles would
be slightly increased by the diurnal libration, which I have not
taken into account.

On October 14th, 1870, the disappearance of ζ *Tauri*, at the
Moon's bright limb, was seen to be accompanied by similar
phenomena by Mr. W. H. M. Christie, at the Greenwich Ob-
servatory, though the duration of the appearance is not given.
On this occasion the Moon's libration was 5° 3′, of which 4° 47′
was effective at the point of occultation. The Moon being only
40^m west of the meridian, the diurnal libration would only *very*
slightly increase these angles.

Another Greenwich observer, Mr. Dunkin, has noted the pro-
jection at the bright limb, upon the reappearance of α *Geminorum*
upon April 4th, 1854, the duration given being 4 seconds. The
libration calculated for this observation is 4° 6′, of which 3° 43′
was effective at the point of reappearance. The diurnal libration
tends to diminish the angles, but it is noteworthy, that the occul-
tation took place very near the south point of the Moon, and hence
at an acute angle with the limb, a circumstance which would tend
to give a considerable duration to the phenomenon, even if the star

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* This occultation has been reduced by the same method as that in use at
the Cambridge Observatory, the *actual* time of disappearance having been taken
(not that of contact with the apparent limb), and for the result it has been
found that the left hand members of the final equations for the disappearance
and the reappearance differ only by 0″·7. The motion of the Moon's limb
would have been more than 3″·0 in the interval of projection. Whether the
phenomena be regarded as optical or physical, it appears strange that some
observers in similar cases have taken the time of apparent contact with the limb
as that of the true disappearance.

had only been projected a short distance within the limb.   Mr. Dunkin's note would seem to bear out this remark.

A fourth instance is recorded by Mr. Talmage at Leyton, on March 19th, 1866, at the disappearance of 31 *Arietis* at the dark limb.   The libration has been found to amount to 3° 27′, of which 2° 52′ was effective at the point of occultation, which has been assumed from the *Nautical Almanac* as the same as for Greenwich. The diurnal libration would increase these angles, making them about equal to those of the previous example, similarly corrected. Neither of these two last instances is sufficiently strong to support the hypothesis alone, though they certainly do not contradict it ; and it is always open to suppose the occultation to have taken place in a valley or depression, which would be equivalent to a sensibly augmented libration.

These are the only instances I have been able to discover during the past twenty years, but there is one case recorded in the *Greenwich Observations*, which is deserving of some consideration from the circumstances, that *two* observers noted the hanging upon the limb for five seconds after the reappearance of the star.   This happened at the occultation of *Regulus* upon May 19th, 1858, Calculating as before I find the total libration to amount to 7° 10′, and at the point of reappearance to 6° 58′.   The diurnal libration slightly decreases the angles.

The cases adduced may not be sufficient to warrant the conclusion that a lunar atmosphere exists and is the cause of this troublesome and anomalous peculiarity ; but it is hoped they are sufficient to show, that there is strong *primâ facie* evidence in favour of the supposition, more than enough to render the careful observation of occultations highly desirable. It may be urged that the theory proves too much, and that since the Moon is so rarely near the state of mean libration, the phenomenon should occur at either the disappearance or reappearance of many occulted stars. It may be replied, that its occurrence at the dark limb must always be invisible, unless that limb be well illuminated by earthlight, which happens but seldom, and that at the bright limb, especially if a reappearance, the observation is one of such acknowledged difficulty, that an observer is both fortunate and sharp-sighted to detect it.   Moreover, the majority of observed occultations are those happening before the full moon, and of the comparatively few observed after, it is only in those of bright stars that the phenomena can fairly be expected to be seen.

There is, however, a possibility that the existence of a lunar atmosphere might be established in an entirely independent manner by the spectroscope, and I am unaware that libration has yet been taken advantage of for this purpose.   The observation would be a delicate one, as only very slight density of atmosphere is possible. The Durham Observatory is supplied with no more powerful instrument than a Browning star-spectroscope, furnished with two 30° prisms, and is therefore manifestly ill suited for undertaking

such an inquiry. I have attempted the observation with this instrument, it is true, but I need scarcely add, unsuccessfully.

Durham Observatory,
  Feb. 22, 1873.

P.S.—In the *Memoirs of the Royal Astronomical Society,* vol. xxviii. pp. 117, *et seq.* there are recorded no less than six cases of projection seen by Captain Jacob at the Madras Observatory in the short space of sixteen months, all of which I have steadily ignored. They are all noted as distinct cases of projection, but no estimate of the duration or the distance from the limb is given. Respecting two of them, however, a note may be found in the *Monthly Notices,* vol. xvii. page 17, written only eight days after the observations were made, in which that meritorious observer expresses himself far more doubtfully, and indeed appears to describe elaborately all the peculiarities of a case of " hanging upon the limb." This leads me to question, whether Captain Jacob ever saw a star fully projected on the disk, and to reject his observations as doubtful. I am unaware whether the Astronomer Royal, who places these observations in the list of certain projections, had any further evidence to guide him in this matter.

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*Note on Mr. Plummer's Paper on the Apparent Projection of
  Stars.* By Richard A. Proctor, B.A., Cambridge.

It is commonly assumed that if the Moon's figure be such as Hansen supposes (though it must be remembered that Newcomb disputes Hansen's conclusion), the atmosphere would be on the further hemisphere of the Moon, and disposed symmetrically around the point antipodal to the centre of the visible disk at the time of mean libration. But I conceive that a very different arrangement would take place,—the densest part of the lunar atmosphere lying round the parts of the Moon which form the outline of her disk at the time of mean libration. Let us assume, with Hansen, that the Moon's surface is formed of two spherical surfaces, the part nearest to us having the least radius, so that in fact the Moon is shaped like a sphere to which a meniscus is added, said meniscus lying on the visible hemisphere. If we imagine the meniscus removed, the lunar atmosphere would dispose itself symmetrically round the Moon's spherical surface. Now, suppose that while this state of things exists, the lunar air within the region now occupied by the meniscus of solid matter is suddenly changed to matter of the Moon's mean density, what could be the effect of this change, by which new matter would

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